**A New Concept Study for Exploring and Sampling Recurring Slope Lineae (RSL) and other Extreme Terrains**, R.C. Anderson[1], I. A. D. Nesnas[1], L. A. Kerber[1], J. W. Burdick[2], F. Calef III[1], G. Meirion-Griffith[1], T. Brown[1], J. Sawoniewicz[1], A. Stefanini[1], M. Paton[1], M. Tanner[2]. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA, [2]Engineering and Applied Science, California Institute of Technology, Pasadena, CA 91109, Robert.C.Anderson@jpl.nasa.gov

*Introduction:* Recurring Slope Lineae, RSL, are terrain discolorations that meet three criteria: 1) they increase in length, 2) they fade, and 3) the periodically recur. They have been observed on some martian crater walls during the warm seasons. Their seasonal behavior and preferential occurrence on warm equator-facing slopes suggest that some volatile, such as liquid brines, may be involved. Since their discovery in 2011, several hypotheses have been proposed to explain this phenomenon. In 2015, signatures of hydrated minerals were detected from the MRO mission imaging spectrometer, providing further evidence that supports the hypothesis of "briny seeps." However, questions remain regarding the mechanism for replenishing the water. Since RSL have only been observed on slopes at the angle of repose of the regolith, others have hypothesized that these features result from dry avalanches possibly triggered by sublimation of frozen $CO_2$ along crater walls. To date, there has been no single hypothesis that can explain all current observations. A JPL study on the Exploration of RSL and gullies took place in June. A consensus has emerged from that study that a mission to explore RSL would have to provide *in situ* measurements on RSL to be able to disambiguate among the various hypotheses.

*Approach and Results:* Our first-year effort was split into two phases. The first phase focused on understanding RSL based on orbital imagery, developing a science traceability matrix, and investigate trades for accessing RSL. The second phase focused on advancing rappelling mobility technology by designing and fabricating a tether management system for the Axel rappelling rover.

RSL Hypotheses: There are currently three hypotheses for explaining RSL: (1) dry flows [1], (2) volatile-triggered dry flows (either CO2 or H2O triggered) [2], or (3) wet flows either from deliquescence [3], from shallow water sources [4], or from deep underground aquifers. Information about RSL can be gathered from multiple assets (Fig. 1): (i) orbital, (ii) distal (here defined as a near-surface at > 1 km from the RSL source), (iii) proximal (from a 1 km to 1 m), and (iv) contact referring to assets < 1 m to the surface. We examined "what can be learned" from each of the four asset types based on required observations that fall in these three categories: (1) characterization and distribution of RSL, (2) a positive water signature, and (3) a negative water signature. Without proximal or contact measurements, we are unlikely to be able to disambiguate a negative water signature or identify the water source for a positive signature.

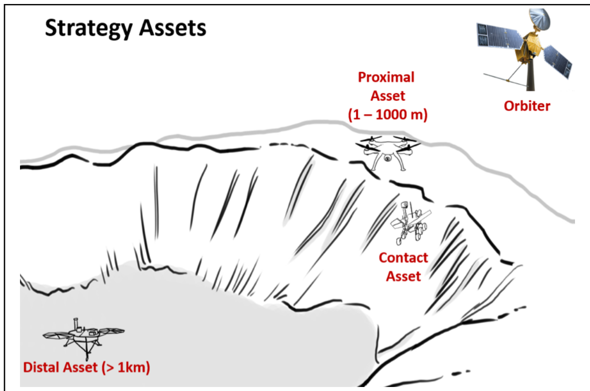


Fig. 1 Asset typs for accessing RSL.

Accessing RSL: We examined over 22 possible concepts for accessing RSL, which can be sorted into the following categories: (1) surface ascent (crater floor up), (2) surface descent (crater rim down), (3) aerial (both balloon and rotary winged aircraft), (4) missiles, and (5) tether riders. Most of these concepts are challenged by the topography of the terrain and its terra-mechanical properties. For each of these concepts, we investigated, on first order, the feasibility, benefits, challenges, and rules of thumb based on expert knowledge from inside and outside of JPL.

At the outset of this task, there was a preference for architectures that landed inside the crater over ones that landed near the rim, since the former would allow line-of-sight measurements of RSL from the landing location. However, given the aforementioned analyses of known RSL, there are very few craters that are large enough for landing therein.

**Balloons**: Tethered balloons and controlled blimps can be used for reconnaissance and/or for delivering a payload on the RSL. Some of their advantages include: (1) obviating the need to scale the crater wall, (2) providing an improved view-shed for multiple observations, (3) supplying power and communication to the payload, and (4) offering improved payload-mass scaling relative to balloon mass.

**Helicopters**: Helicopters would be expected to be deployed from a larger asset such as a lander or rover. Both rim and crater floor landing options are considered viable, but it is believed that such an activity would add significant complexity and risk to the mission. Similar to balloons, helicopters can also be used for proximal measurements and/or delivering payloads.

**Missiles:** Missile concepts are attractive because they can deliver large payloads in a short period of time either by impacting the site of interest or through a more controlled descent of a payload à la MSL skycrane. We investigated several concepts that included missiles powered by compressed $CO_2$, solid and liquid propellants.

**Ground ascent**: This high-heritage option would largely depend on the assumed terrain properties, both topographic and mechanical. Clearly, the most significant challenge to the upward ascent of an RSL bearing crater wall are the slopes which increase slip and sinkage during locomotion that could lead to immobilization. Furthermore, approaching the RSL from the crater floor will also likely encounter boulder fields, large obstacles and sand ripples. State-of-the-art rovers are designed for a maximum of 20°–25° slopes. Numerous vehicle designs and field results has been investigated [5], but the slopes and boulders may perhaps present unsurmountable challenges for an ascent vehicle.

**Ground descent**: Ground-based descent rovers offer one principal advantage over ascent rovers. They work with gravity rather than against it. They can be broadly categorized as tethered or untethered. Whether tethered or not, they will need to be capable of traversing several km of relatively benign terrain from the lander to the crater rim. They should then be capable of ascending modest 5° –15° inclines of mixed terrain to the rim of the crater, before beginning their descent. Untethered descent (Fig. 2), such as [6] offers the advantage of reducing the risk of tether snagging or entanglement, however, they are subject drop offs from large terrain features, sliding due to terrain weakness, and a likely inability to return to a parent vehicle. Alternatively, a tether provides multiple benefits: (1) it enables communication and power relay between a lander/rover and the descending unit, (2) it provides a safety net capable of arresting a fall or slowing an unintended slide, and (3) it obviates the need for exceptional tractive capabilities by enabling the winching of the vehicle back to the crater rim [7].

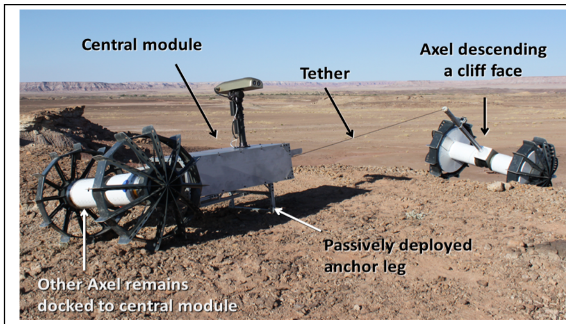


Fig. 2 DuAxel rover with a rappelling Axel.

*Significance of Results to Date*

Considering the trades for accessing RSL, its appears that tethered descent may hold promise when compared to alternatives. Further understanding of tethered rover operations in extreme terrain under mission-like constraints would be important to inform future missions. Current field results, on a limited set of terrains, indicate feasibility of such operations using solely rover's on-board sensors, but further investigations are warranted in particular for sensing and tether management.

*References and Publications*

[1} F. Schmidt, et al., *Nature Geoscience*, 10:270–273; 2017. [2] C Pilorget and F. Forget, *Nature Geoscience*, 9:65–69; 2015. [3] J. Heinz, et al., *Geophysical Research Letters,* 43:4480–4884; 2016. [4] A. McEwen, et al., *Nature Geoscience*, 7:53; 2013. [5] G. Meirion-Griffith, et al., *Aerospace Conference* 2018. [6] X. Xiong, “Supervised Descent Method,” Ph.D. dissertation, Robotics Institute, CMU, 2015. [7] I. A. Nesnas, J. Matthews, P. Abad-Manterola, J.W. Burdick, et al, *Journal of Field Robotics*, June 2012.